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Producing Woodfuel for Urban Centers in the Democratic Republic of Congo: A Path Out of Poverty for Rural Households?

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Summary. — Woodfuel is a renewable energy source with good potential for climate change mitigation. In the Democratic Republic of Congo (DRC), the sector employs over 300,000 people for the supply of Kinshasa alone, but the benefits to the poor are often unknown. This paper analyzes the contribution of commercial woodfuel production to livelihoods and poverty reduction in the DRC. Woodfuel revenues, especially those of charcoal, contribute substantially to producers' household income, ranging from 12% for fuelwood producers around Kisangani to 75% for charcoal producers around Kinshasa. It supports basic needs and investments in other livelihood activities (for 82% of charcoal producers and 65% of fuelwood producers), which helps to reduce poverty. The contribution of woodfuel commercialization to poverty reduction should be part of energy and forestry policies.
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Key words — charcoal, fuelwood, livelihoods, Africa

1. INTRODUCTION

Woodfuel [1] can provide renewable energy, if the resource is managed sustainably, (Trossero, 2002), but it is often regarded as an inferior fuel in developing countries. International institutions dealing with energy and development generally present woodfuel as a "traditional" energy source that needs to be replaced (Hiemstra-van der Horst & Hovorka, 2009; Openshaw, 2011). The adverse health impacts of indoor-cooking smoke and the detrimental impacts on forest resources are the main negative associations with the sector (Guzmán and Hoz-Restrepo, 2008; Smith, 2006). Growing demand for woodfuel in urban areas has increased pressure on forest resources, which is especially problematic in the absence of incentives to restore or manage these resources sustainably (Hofstad, 1997; Marien, 2009; Schure et al., 2012). Many international institutions present woodfuel as unsustainable, despite the fact that there is sufficient woody biomass to meet the demand in most countries (Openshaw, 2011). The sector also creates rural development and employment (Arnold, Kohlin, & Persson, 2006; Marien, 2009; Sankhayan & Hofstad, 2000). In the first wave of woodfuel studies in the 1980s, it was already noted that the woodfuel story is complex and needs to consider the specific landscapes and livelihoods of those involved (Leach & Mearns, 1988). However, there are still few quantitative studies about the exact income contributions to producer households and to poverty reduction (Angelsen & Wunder, 2003; Arnold *et al.*, 2006; Hyde, Kohlin, & Amacher, 2000). This knowledge is relevant especially considering both the growing commercial woodfuel sector in Sub-Saharan Africa and the concentrated urban demand (Marien, 2009). Sustainable management initiatives and climate change mitigation policies that affect the woodfuel sector should not be addressed without a deep understanding of the possible outcomes on poverty.

This research aimed to analyze the contribution of the woodfuel sector to livelihoods of producers engaged in the urban woodfuel supply in the Democratic Republic of Congo (DRC). The DRC has abundant natural resources with roughly 130 million hectares of tropical forest, representing 60% of the Congo Basin forests. It is also one of the poorest countries in the world, being the last of 187 countries on the Human Development Index (United Nations Development Programme, 2011). Despite its size, there are little data available on the

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woodfuel sector in the Congo Basin, mainly because of the sector's informal character. Recent observations in the DRC show an increased demand of urban woodfuel as a result of the growing population, the lack of alternative energy sources, and a shift from consumption of fuelwood to charcoal (Schure *et al.*, 2012). Households depend largely on woodfuel for daily cooking (87% in Kinshasa and 95% in Kisangani). Businesses, such as bakeries, breweries, restaurants, brick makers, and aluminum forgers also use fuelwood or charcoal for their daily operations (Schure, Ingram, & Akalakou-Mayimba, 2011). The national program for Reducing Emissions from Deforestation and Degradation (REDD+) and its Forest Investment Program (FIP) (endorsed in June 2011) put an important focus on the woodfuel sector regarding potential production and consumption efficiencies to be gained (Ministry of Environment & Nature Conservation & Tourism, 2011). Related policies need to consider whether woodfuel markets contribute to poverty reduction, especially of producers who form the majority of actors in the chain from producer to consumer: While 15,000 are employed in DRC's formal forestry sector, around 290,000 people are involved (at least part time) in woodfuel production for the six-million inhabitants of the city of Kinshasa alone (Schure, Ingram, Marien, Nasi, & Dubiez, 2011).

(a) *Historical overview: Woodfuel and nontimber forest products, an alternating agenda?*

Attention to woodfuel production and consumption has fluctuated over the past decades.[2] In the 1970s, concerns about woodfuel shortage, known as "the other energy crisis", were triggered by the oil crisis (Eckholm, 1975). Within the context of the "basic needs approach", many studies predicted a "woodfuel gap" between demand and supply leading to depletion of forest resources with detrimental environmental and socio-economic impacts on the poor. Woodfuel became a policy priority and large-scale woodfuel plantations and efficient-stove projects were implemented to assure woodfuel supplies. A decade later, in the mid-1980s, the woodfuel crisis did not materialize on a global scale as increasing urbanization and rising incomes slowed demand in many regions (Arnold, Kohlin, Persson, & Shepherd, 2003). The "woodfuel gap" proposition was criticized for its large-scale approach and guesswork regarding data on woodfuel consumption and tree stocks (Leach & Mearns, 1988). It was found that woodfuel was sourced from areas other than forests, including from trees on agricultural land, village woodlots, home gardens, and public land, or consisted of "deadwood," dry branches, and other plant materials (Trossero, 2002). In cases where local households were faced with less supply, they often coped by reduced consumption and by using alternative cooking fuels such as plant waste and cow dung. Charcoal became more popular in urban markets because of its higher energy density and lower smoke-production compared to fuelwood (Arnold *et al.*, 2003). Although the role of woodfuel commercialization was recognized, little attention was given to how such trade contributed to household incomes. By the late 1980s, attention to the "woodfuel crisis" and related intervention schemes had waned considerably (Arnold *et al.*, 2006).

In the early 1990s, leading up to the 1992 UN Conference on Conservation and Development, NonTimber Forest Products (NTFPs) became more visible on the development and environment agenda, following the publication of Peters, Gentry, and Mendelsohn (1989) and others indicating that the value of NTFPs can be higher than of wood. The reasons why woodfuel was largely ignored in this new NTFP agenda were that it was primarily regarded as a subsistence resource, and that as a wood product it did not present a sustainable harvesting scenario (Sills, Shanley, Paumgarten, Beer, & Pierce, 2011). The quickly increasing number of NTFP studies that started in the mid-1990s provided insights on the roles of NTFPs related to agriculture, conservation, and poverty reduction. It became clear that forests play diverse roles in local livelihoods, which pleads for a "resource-in-context approach" (Ros-Tonen & Wiersum, 2005). The earlier high expectations about reconciling environment and development objectives were lowered (Arnold & Perez, 2001; Ros-Tonen & Wiersum, 2005). Moreover, there was recognition of the growing prevalence of urban and peri-urban residents involved in NTFP trade. The NTFP studies gradually broadened their scope to include "a range of forest products (from medicinal plants to timber), a range of forest management intensities (from pure extraction to intensive forest management), and a range of markets (from international to local)" (Sills *et al.*, 2011: 43).

The 2000s saw renewed interest in the woodfuel sector. On an international level, the renewable potential of woodfuel was recognized and climate change politics took an interest in its possibilities for carbon sequestration and reducing greenhouse emissions (Bailis, 2009; Trossero, 2002). Van Ruijven *et al.* (2008) argued that energy and development models often originate in the developed world and need to fit the reality of many developing countries, where the sector is more complex than initially thought. This echoes Leach and Mearn's (1988) early criticisms about the lack of attention to the local context in dealing with woodfuel issues. The importance of considering the full range of livelihood activities is illustrated by studies of pioneer farmers in the Amazonian rainforest for whom production of charcoal simultaneously increased income and decreased deforestation by offering an alternative to agricultural expansion (Labarta, White, & Swinton, 2008). However, it also became clear that concentrated woodfuel demand, often related to land clearance for agriculture, can be a driver of deforestation (Marien, 2009; Mwampamba, 2007). This is of particular concern in Africa, where household woodfuel consumption is expected to increase in the coming decades along with increasing urban demand for charcoal (Girard, 2002). A review of the woodfuel sector of 18 African cities by the Food (2010) highlighted large variations in environmental effects: from low pressure and weak impact to accelerated degradation of peri-urban areas. A similar variation is expected for producers' livelihoods. The role of woodfuel as a source of revenue was seen as deserving more attention, given that fuelwood and charcoal are important providers of employment (Sankhayan & Hofstad, 2000; Vedeld, Angelsen, Bojo, Sjaastad, & Kobugabe Berg, 2007). In this respect, woodfuel studies can learn from recent NTFP studies and their focus on livelihoods and combinations of markets and resources.

(b) *Conceptual framework: Placing woodfuel in the context of livelihood strategies and poverty reduction*

For the whole of Sub-Saharan Africa it is estimated that 13 million people are employed in the biomass (mostly wood-) energy sector (Openshaw, 2010). The importance of woodfuel income and its contribution to the livelihoods of producer households has been highlighted, but few quantitative studies are available. Woodfuel production shows pro-poor features because of the low start-up costs, low technology, and few skills needed, which makes it relatively accessible (Angelsen & Wunder, 2003). However, competition may be high and the actual profits small. It is often unknown whether the revenues are enough to lift households out of poverty (Arnold *et al.*, 2006). For this we need to understand how value is added over time and whether poverty reduces, but detailed data on costs and benefits and the actual returns to producers are mostly lacking in the informal sector (Neumann & Hirsch, 2000; Openshaw, 2010). Recent studies offer some insights into the extent to which the woodfuel sector contributes to poverty reduction, providing income to rural (Shackleton, Shackleton, Buiten, & Bird, 2007) and urban poor. For example, around urban centers in Uganda, charcoal revenues were found to contribute positively to annual household cash incomes by on average 122 USD per adult equivalent (Khundi, Jagger, Shively, & Sserunkuuma, 2011). In this case, the poorest of the poor rarely participated in the charcoal production (Khundi et al., 2011). In contrast, in Malawi, charcoal revenues did contribute to the income of poorer households (Zulu, 2010). This illustrates the various roles woodfuel revenues can play in different contexts.

A combination of livelihood strategies can help mitigate and reduce poverty. Poverty mitigation, related to forest products, is considered as "the use of forest resources to meet household subsistence needs, to fulfill a safety net function in times of emergency, or to serve as 'gap filler' in seasonal periods of low income [...]. Poverty reduction in contrast is defined as "the use of forest resources to help lift the household out of poverty by functioning as a source of savings, investment, accumulation, asset building, and lasting increases in income and well-being" (Sunderlin *et al.*, 2005: 1386). Wealthier and poorer households are likely to derive different kinds and quantities of benefits from forest products. Wealthier households may possess more land, enabling them to freely access resources, reduce production costs, invest in value-adding, and transport to urban markets, and so capture higher prices. In contrast, poorer households may depend more on forest products for subsistence income and be more restricted to local markets (Paumgarten & Shackleton, 2009).

How commercial woodfuel production contributes to poverty reduction depends also on how revenues are spent, saved, or invested. Spending on food, healthcare, education, shelter and clothing, meets basic needs. Durable assets that poor people accumulate can serve as safety nets in times of need. These in-kind savings can spread the risk of unpredictable and uncertain incomes and provide a buffer (Deaton, 1990). Saving cash can be especially challenging for the poor, as institutional mechanisms that facilitate saving, such as banks, financial education, and saving incentives, are often not in place and financial assets are under pressure of family demands (Beverly & Sherraden, 1999; Gugerty, 2007). Households may use a range of different mechanisms to insure themselves and accumulate capital such as: borrowing from neighbors, buying, and selling assets and diversifying production, in which the collection and trade of forest products serves as a "natural insurance" mechanism (Morduch, 1994; Pattanayak & Sills, 2001).

(c) *Objective, research questions and hypotheses*

Building upon the insights derived from NTFP and livelihood studies, this paper assesses the role of woodfuel production and trade in local livelihoods. The objective was to analyze the contribution of the commercial woodfuel sector to livelihood strategies of producers in the supply zones around the urban centers of Kinshasa and Kisangani in the DRC. It was guided by the following research questions:

(1) What is the role of commercial woodfuel production in the livelihood strategies of producer households?

(2) How does commercial woodfuel production affect income and poverty in producer households?

(3) How does poverty affect commercial woodfuel production?

Three analytical hypotheses were distilled from the conceptual framework, to be confirmed or rejected by the research results:

(1) Woodfuel commercialization contributes to diversifying producers' household incomes.

(2) Income generated by commercial woodfuel production is limited (less than 25%) and finances mainly basic needs, indicating the modest contribution of woodfuel to poverty reduction.

(3) Despite the pro-poor features of commercial woodfuel production, the poorest income groups benefit least, as they have fewer options to add value.

2. METHODOLOGY

(a) *Study area*

The study area covers the supply zones for woodfuel to DRC's capital Kinshasa and Kisangani, capital of Orientale Province (Figures 1 and 2). These two cities were selected because of their high woodfuel demand, although this is considerably higher in Kinshasa because of its higher population and greater distances to wood resources for the urban population. In 2010, the total volumes of woodfuel supplied in urban markets were around 4.8 million m^3 in Kinshasa and 200,000 m^3 in Kisangani (Schure, Ingram, & Akalakou-Mayimba, 2011). The two sites allow a comparison of an area containing savannah and degraded forests zone around Kinshasa with abundant forests around Kisangani.

Kinshasa is situated on the south bank of the Congo River, and is the second most populated city in Sub-Saharan Africa after Lagos. It is supplied with woodfuel largely from the provinces of Kinshasa and Bas-Congo (43% and 34% respectively). The supply zone stretches to the southwest and northeast over an average distance of 102 km for fuelwood and 135 km for charcoal. The rolling landscape of the Plateau Batéké contains mainly savannah with riverine gallery forests. The remainder of woodfuel supplying Kinshasa (23%) arrives via the Congo River from the provinces of Bandundu, Equateur, and Orientale up to 1000 km away (Schure, Ingram, & Akalakou-Mayimba, 2011).

Kisangani, in the northeast of the country, is situated in a lowland tropical humid forested plain that extends to the southwest. Woodfuel supplies enter the urban area by six main river and road routes. The supply zone stretches over an average distance of 25 km for fuelwood and 37 km for charcoal (Schure, Ingram, & Akalakou-Mayimba, 2011). The population of this region is poorer than the population in the other main supply sites under study (Kinshasa and Bas-Congo province) (Table 1).

(b) *Methods and materials*

Surveys were conducted with people who indicated that they produce and sell fuelwood or charcoal as one of their activities. In the supply zones of Kinshasa, 200 fuelwood producers and 392 charcoal producers, and 73 fuelwood-producers and 409 charcoal-producers from the Kisangani supply zone were interviewed between September 2009 and February 2010. Respondents were randomly selected in 14 villages in the Kinshasa Province, 12 villages in the Bas-Congo Province and 26 villages in the Orientale Province. These villages had been identified based upon interviews with transporters and experts mapping the geographical distribution of production regions. Household level economic, social, and environmental aspects

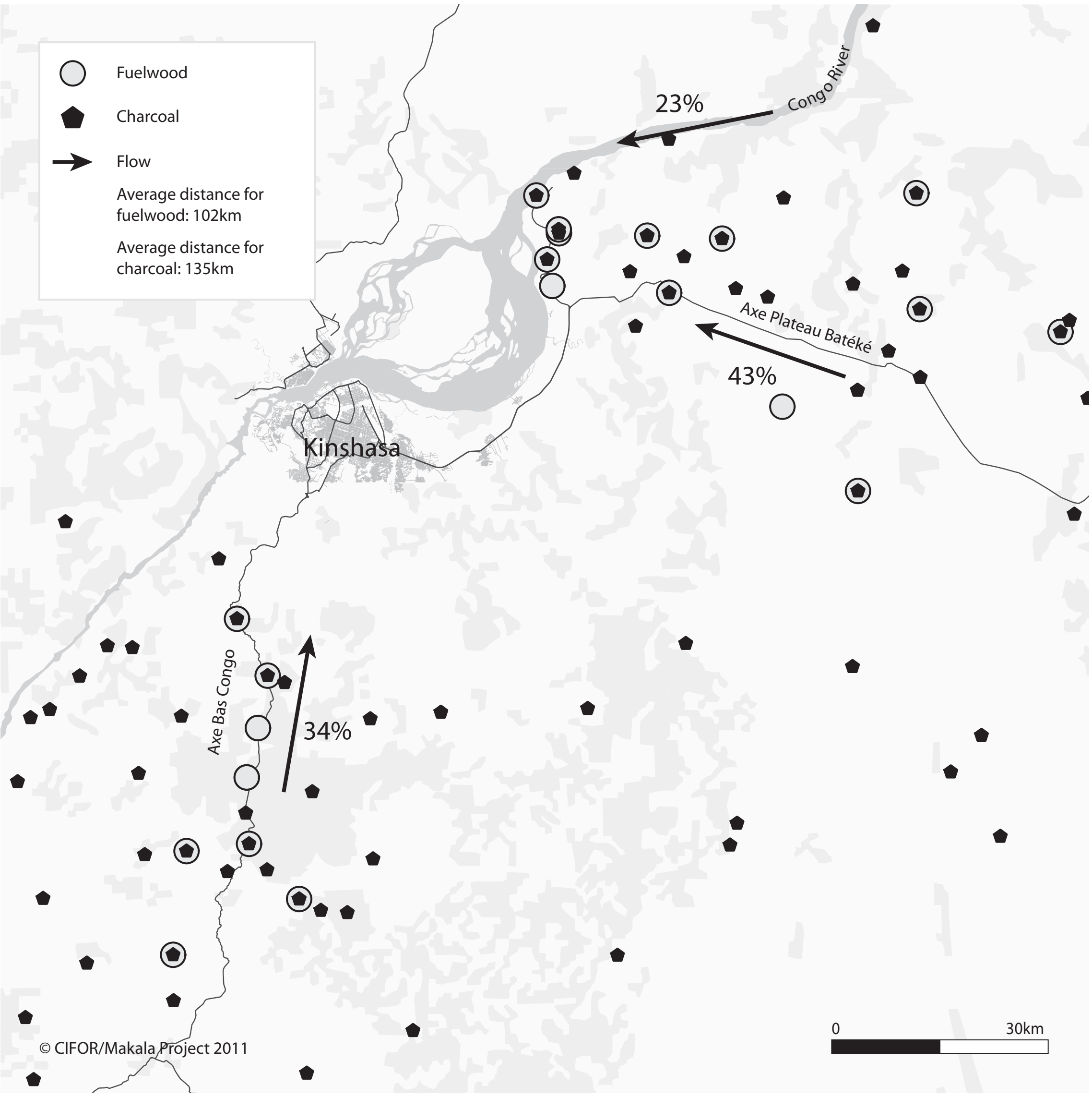

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Figure 1. *Kinshasa supply zones and woodfuel inflow.*

of woodfuel production and trade were addressed in the structured questionnaire.[3] From May 2010 until April 2011, a year-long survey was conducted with producers in 10 villages in the Kinshasa supply zone and seven in the Kisangani supply zone. Producers kept records of costs, prices, and production volumes that were verified and collected monthly to determine fluctuations and average cost structure. In April 2011, 49 in-depth semi-structured interviews and 12 group interviews were conducted in 12 villages in the supply zones to collect data on saving and spending patterns. A statistical software package (SPSS 16.0) was used to analyze the data. Descriptive statistics were used to illustrate the socio-economic profile of producers. The annual net profit and return to labor of producers were calculated:

n = number of units sold,
P = average selling price,
MD = number of man–days or labor input,
Wc = Labor cost,
Σ^C = Total cost = Transportation + Taxes + Equipment + Access to resource + Wc,
Annual net profit = $n * \mathrm{P} - \Sigma^c$,
Return to labor = $(n * \mathrm{P} - \Sigma^c + \mathrm{Wc})/\mathrm{MD}$.

Statistical analyses (Chi-Square test for independence, independent-samples T-test and one-way between groups ANOVA) were conducted to compare differences between groups (per region, income level, and type of product). Continuous data on production quantity were analyzed using a logarithm to transform the data into a normal distribution to meet assumptions for parametric tests (T-test and ANOVA).

3. RESULTS

(a) *Role of woodfuel in the producers' livelihood strategies*

Producers in the supply zones of Kinshasa and Kisangani are mostly villagers who live and work in their village of origin. Fuelwood production, from cutting the wood to packing bundles for sale, is often done by family members and sometimes other villagers are hired for a daily fee or in kind compensation. Temporary urban-to-rural migration was observed to some extent, especially for large-volume producers of fuelwood for

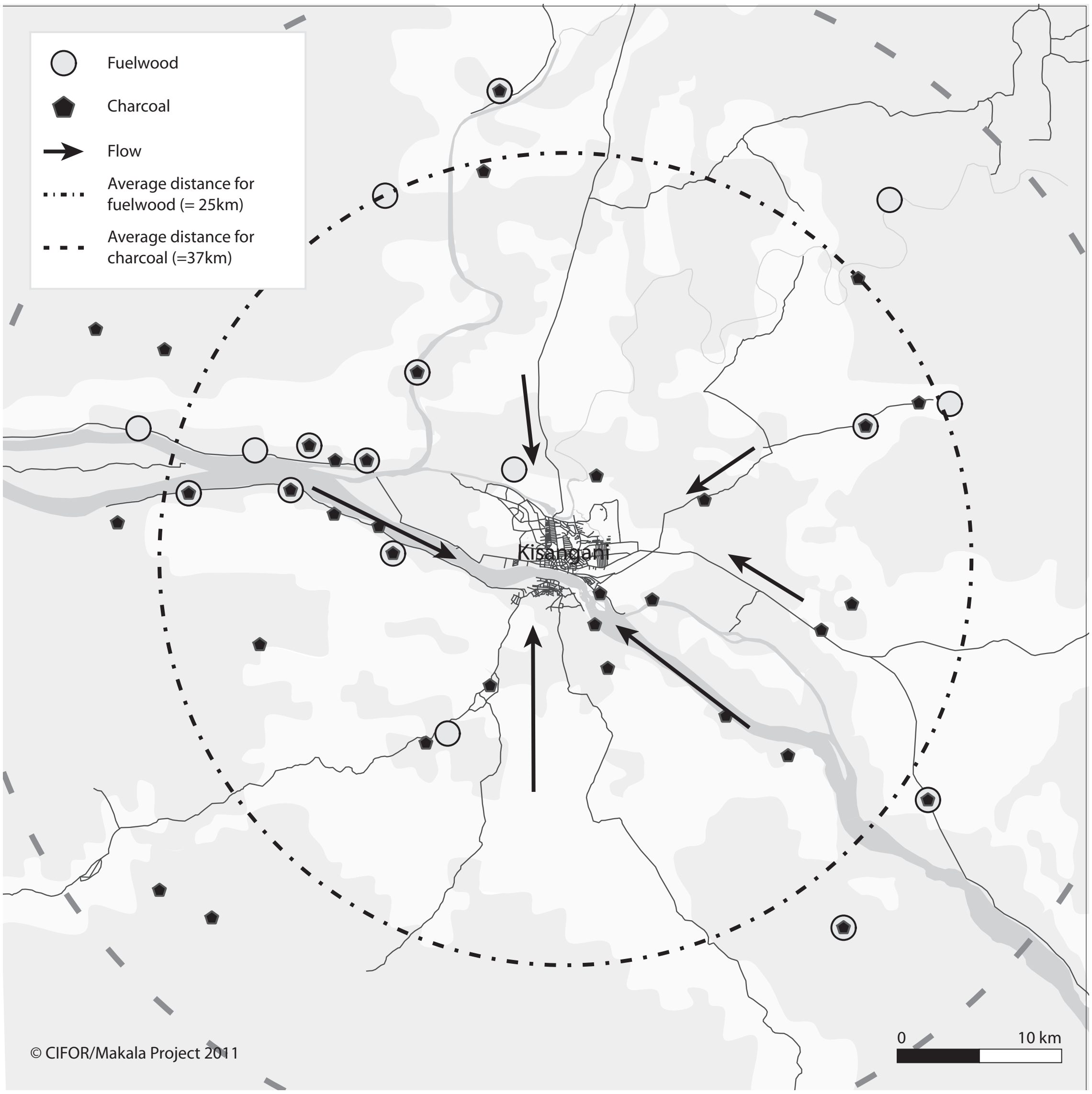
Fuelwood
Charcoal
Flow
Average distance for fuelwood (= 25km)
Average distance for charcoal (=37km)
Kisangani
© CIFOR/Makala Project 2011
0
10 km

Figure 2. *Kisangani supply zones and woodfuel inflow.*

Table 1. *Socio-economic status of Kinshasa and Kisangani research locations*

	Kinshasa		Kisangani	DRC
	Kinshasa Province	Bas-Congo Province	Orientale Province	
Surface (km^2)	9,965	55,920	503,239	2,344,858
Population (millions)	5.8	3.2	6.6	64.3
Poverty rate (%)	41.6	69.8	75.5	71.3
Average household size	6.0	4.8	4.7	5.3
Primary school education rate (%)	74.8	71.1	76.6	76.3
Underemployment[a] (%)	53.1	73.4	71.9	72.7
Origin of household income (%)				
Informal sector	89.5	93.6	95.9	94.6
Public sector	6.1	4.0	2.9	3.6
Private sector	4.4	2.4	1.3	1.8
Average monthly household income (USD)	84	37	25	42

Source: United Nations Development Programme, 2009.

[a] Underemployment: people who involuntarily work less than 35 h a week or earn less than the minimum salary.

bakeries. The production cycle for charcoal, from cutting the wood to packing bags, mainly involves local men who are paid a daily fee (or sometimes a percentage of the production) by the landowner or the "head producer." In both regions, reciprocal labor exchange groups ("*ristourne*") are common. These involve around ten producers working in turns to build one member's charcoal kiln. The host producer provides drinks and food and reciprocates by working on other members' kilns. Some urban citizens have also specialized in charcoal production. They mainly function as intermediaries and finance providers, hiring local villagers to produce charcoal. Producers of woodfuel represent average rural households in terms of working-age population and ethnic groups. Average total household income of producers in the Kinshasa supply zone is less than the international 1.25 USD per day poverty line standard, but is similar to other rural households in the region (cf. Tables 1 and 2). In Kisangani, the average producer household income is higher than the provincial average. This might be explained by the fact that the households of the study are larger than average and live relatively close to the urban markets (compared to the province's average household).

Agriculture is the primary income-generating activity for most producers in both regions. Other revenues mainly come from trading small commodities and timber exploitation. In the Kinshasa region, livestock also provides income; in the Kisangani region fishing generates revenues (Table 3). Producers around Kisangani rely more on NTFP collection and hunting in the more abundant forests. Virtually all producers depend on more than one activity for their household income. Opportunities of salaried employment, even temporary, are rare and only few producers benefit from paid, seasonal jobs.

Woodfuel is mostly sourced by clearing forests for agriculture—either by the woodfuel producer or the landowner (Figure 3). Two-thirds of the woodfuel produced for Kinshasa and Kisangani originate from agricultural activity (reopening of bush fallows in the shifting cultivation cycle), while around one-third comes from noncleared forests: generally degraded gallery forests around Kinshasa and primary forests around Kisangani. For fuelwood for Kisangani this amounts to 85%, meaning that only 15% of commercial fuelwood production comes from forests with no link to agriculture. In Kisangani, the sources where woodfuel is harvested correspond with the preferred sources voiced by producers. Around Kinshasa, however, more producers (22%) would prefer forests and plantations instead of their current sources, as forests generally provide more and larger trees. This highlights the difficulties in finding and accessing new woodfuel resources and the potential for woodfuel plantations.

(b) *Production and net revenues*

There is a significant difference ($p < 0.05$) in the mean production for both products from the two regions.[4] During the study period, producers around Kinshasa produced on average 10.6 tons of fuelwood per year ($\sigma = 16.8$) compared to a significantly larger production in Kisangani of 31.6 tons of fuelwood per year ($\sigma = 23.0$). For charcoal the mean production around Kinshasa was 8.2 tons per year ($\sigma = 9.9$) and around Kisangani on average 10.9 tons of charcoal annually ($\sigma = 14.2$).

For fuelwood producers in Kinshasa, no significant differences ($p = 0.27$) in production quantities were found between different income groups. Conversely, in Kisangani, the lowest income group produced significantly larger quantities than higher income groups (Table 4).[5] Charcoal production in both regions differs significantly (at the $p < 0.001$ level) between the four income groups.[6] The mean production is lowest for the low-income groups and highest for high-income groups (Table 4). In both regions, producer households in the middle range with a monthly income of 51–100 USD produce the highest quantities of charcoal. Households with monthly income over 100 USD have a slightly lower production.

For producers in Kisangani, a significant association was found between household income level and land ownership. For charcoal producers,[7] the richest income group (>100 USD/month) mostly (87%) accesses their own (customary) land for harvesting trees. In contrast, for the poorer households only 35% have their own land, and the majority (65%) pays for access to trees. For fuelwood producers, there is only a small association,[8] with the medium income group (51–100 USD) paying relatively often (41%) for access to trees, compared to poor and richer groups (10% and 14%). In Kinshasa, no significant association ($p = 0.371$) was found for either product. Due to higher pressure on land and resources in this area, just over a third of producers, across all income groups, pays for access to trees.

Woodfuel revenues contribute substantially to average household income: averaging 47% for fuelwood producers and 75% for charcoal producers in Kinshasa, and 12% for fuelwood producers and 38% for charcoal producers around Kisangani. There was no significant relation[9] between the level of household income and place where woodfuel was sold. Across all income groups, a fifth of producers sell in the village while most producers (80%) bring their product to urban markets. Woodfuel is produced mainly for cash income; only small quantities (<10% of fuelwood and <5% of charcoal) are exchanged for goods or consumed. The net profits[10] are highest for charcoal and in the Kinshasa region (Figure 4).

Labor returns for fuelwood production are somewhat below the average regional income in the Kinshasa supply zone (0.70 USD per day) and comparable to the average for the Kisangani zone (0.80 USD per day) (United Nations Development Programme, 2009). The rate of return per man–day for charcoal production in both regions is relatively high: 1.95 USD per day in the Kinshasa zone and 1.60 USD per day in the Kisangani zone, which is twice the average regional daily income of adult men (United Nations Development Programme, 2009). This supports the finding that net benefits from charcoal are higher than from fuelwood. Average net

Table 2. *Average value of some socio-demographic variables among charcoal and fuelwood producers*

	Kinshasa region		Kisangani region	
	Charcoal producers	Fuelwood producers	Charcoal producers	Fuelwood producers
Women producers (%)	3.4	5.8	4.9	50.7
Age (years)	34.2	33.6	34.2	42.7
Working experience in woodfuel (years)	7.1	7.5	7.7	14.0
Household size (number of members)	5.4	6.1	6.7	8.3
Total monthly household income (USD)	45	51	65	64

Table 3. *Income-generating activities mentioned by charcoal and fuelwood producers (% of producers who list this activity among their five most important income-earning activities)*

	Kinshasa region		Kisangani region	
	Charcoal producers	Fuelwood producers	Charcoal producers	Fuelwood producers
Agriculture	94.2	89.3	94.2	93.2
Trade in small commodities	20.9	23.5	17.6	17.8
Timber exploitation	10.8	29.1	13.4	9.4
Livestock	9.0	10.2	4.6	4.1
Fishing	1.1	–	10.6	1.4
NTFP collection	2.6	5.1	24.6	34.2
Hunting (bush meat)	2.1	2.6	12.8	12.3
Apiculture	0.8	–	0.6	–
Crafts worker	0.8	5.6	4.3	6.8
Paid seasonal labor	1.6	3.1	3.6	–
Paid full time work	–	–	1.8	–

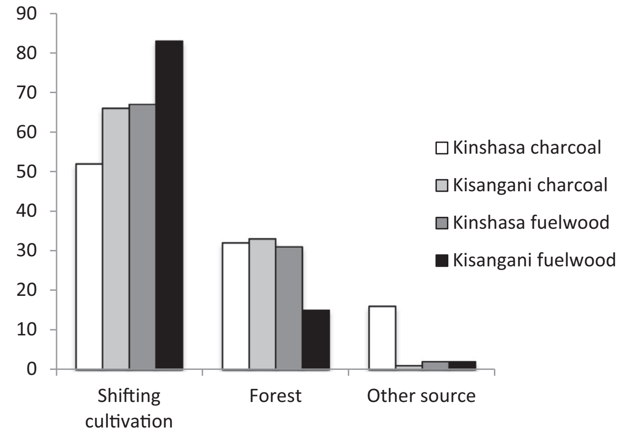

Figure 3. *Sources for charcoal and fuelwood production per city.*

benefits are higher in the Kinshasa supply zone, despite higher average production quantities and lower production costs in the Kisangani supply zone (Table 5), reflecting the higher prices in an area of higher demand and more restricted supply.

(c) *Woodfuel revenues' contribution to poverty reduction*

The benefits from woodfuel income are both short-term (i.e., money used for daily needs) and long-term, where the revenue is invested. Charcoal making involves tough, dirty, physical labor, but it can relatively quickly provide cash, leading to its popular name of "*intervention rapide*." Fuelwood collection is a more continuous activity, not seen as onerous, but like charcoal, it forms one of the few options that producers have to generate a cash income. Another important benefit is that fuelwood and charcoal production can be carried out without neglecting agricultural activities, which for the majority remains the primary source of subsistence. Woodfuel production takes place when cash income is needed and when time is available. This is often during agricultural slack periods, in the months after planting and before harvesting. Villagers make a clear distinction between these different benefits:

> "If there would be only charcoal, the household would have no food. Charcoal doesn't give us *chikwange* [local staple food based on fermented cassava] or [cassava] leaves like our fields do. We make charcoal for one reason: to pay for something."

Revenues from charcoal production and fuelwood are used to pay for daily needs, mainly food, and for cash expenses like education and healthcare (Table 6). The "quick intervention" notion illustrates that it is a "gap-filler" in times of need. This contribution to basic needs and gap-filling function highlight its clear role in poverty mitigation.

The contribution of woodfuel production to poverty reduction is illustrated by the ways in which producers invest part of woodfuel revenues into other household activities. The relatively large sums that can be produced at once contribute to specific household investment patterns that are similar for both regions. The main investment is in agriculture, with a small proportion invested in petty trade, livestock, and fishing (Table 6). These activities are a way of accumulating capital, diversifying income sources, and distributing risk.

For both cities, a significant correlation between income level and investments was found.[11] Among the poorest households (<11 USD per month), 79% of producers indicated that

Table 4. *Mean production of fuelwood and charcoal (tons per year) per producer per income category*

Income group	(USD/month)	Both regions production (tons)	Kinshasa production (tons)	Kisangani production (tons)
Fuelwood				
Low	1 + 2[a]: <50 USD	20.1 ($\sigma = 26.5$)	11.4 ($\sigma = 20.9$)	44.2 ($\sigma = 25.5$)
Mid	3: 51–100 USD	12.3 ($\sigma = 12.5$)	9.2 ($\sigma = 10.6$)	18.8 ($\sigma = 13.7$)
High	4: >100 USD	19.8 ($\sigma = 16.5$)	12.4 ($\sigma = 11.4$)	28.2 ($\sigma = 17.6$)
Charcoal				
Lowest	1: <11 USD	4.3 ($\sigma = 5.2$)	3.5 ($\sigma = 3.7$)	5.3 ($\sigma = 6.6$)
Low	2: 11–50 USD	6.2 ($\sigma = 6.8$)	7.0 ($\sigma = 7.8$)	5.1 ($\sigma = 4.6$)
Mid	3: 51–100 USD	10.4 ($\sigma = 11.5$)	11.4 ($\sigma = 13.0$)	9.1 ($\sigma = 9.1$)
High	4: >100 USD	9.0 ($\sigma = 9.1$)	9.6 ($\sigma = 8.2$)	8.9 ($\sigma = 9.2$)

[a] For fuelwood the one-way between groups ANOVA was conducted with three income groups instead of four (group one and two were combined) to meet the conditions for this test.

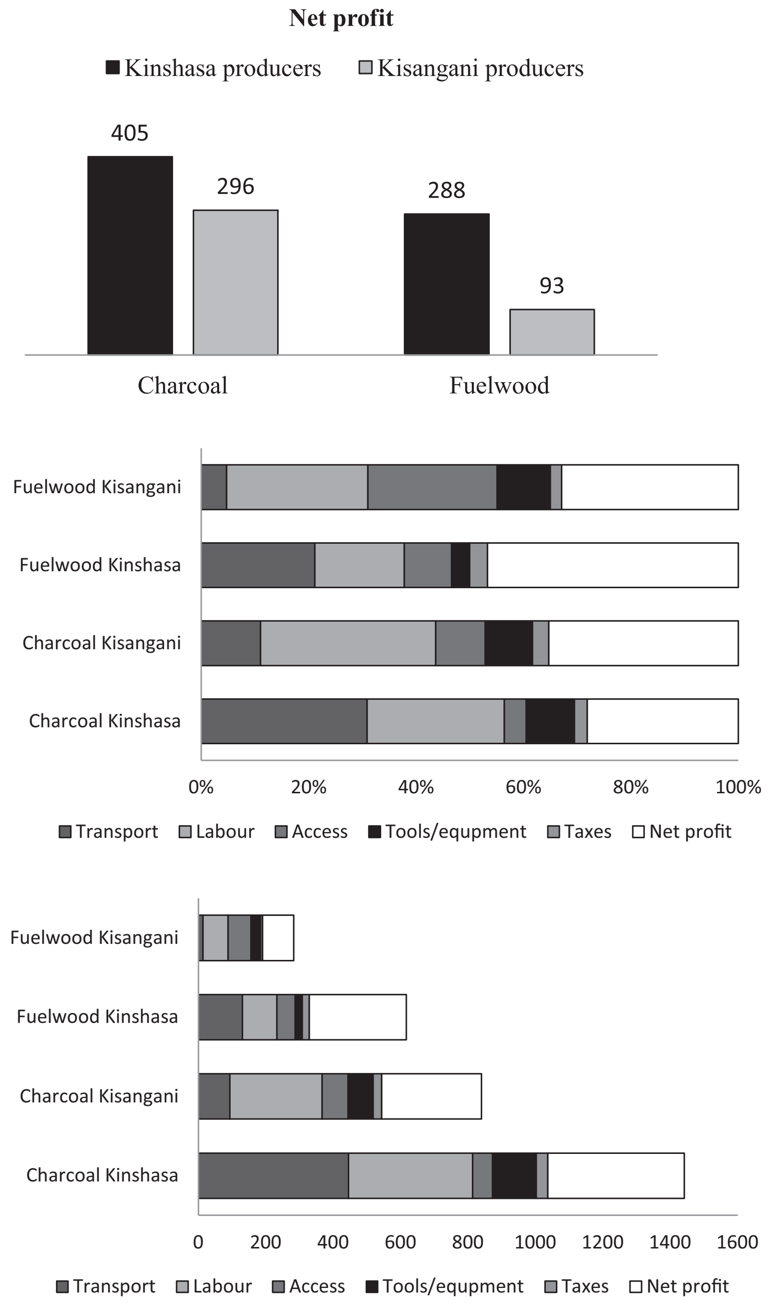

Figure 4. *Costs and net profits of charcoal and fuelwood production for producers.*

Table 5. *Net benefits of woodfuel production per region and per product*

	Kinshasa		Kisangani	
	Fuelwood	Charcoal	Fuelwood	Charcoal
Net benefits per producer per year (USD)	288	405	93	296
Net benefits per ton produced (USD)	27	49	3	27
Net return per man–day (USD)	0.70	1.95	0.80	1.60

they invested part of their woodfuel revenues, whereas in less poor households (11–50 USD per month), 94% of producers invested. Charcoal revenues are almost always (92%) invested, even by the absolute poorest (90%).

Most producers (62%) indicated that they managed to save some of their overall household income. Saving in banks is rare (8%) among producers; over half of the households (58%) keep their cash at home. Saving was also achieved by buying goods, such as telephone cards, which can be resold later (21%) and with informal moneylenders (13%). Savings were mainly spent to cope with possible shocks (family issues, sickness, and funerals) rather than for (planned) investments.

Table 6. *Dimensions of poverty reduction per woodfuel supply zone*

Poverty dimension	Spending pattern	Kinshasa	Kisangani
Poverty mitigation	Producers spending WR[a] on		
	Food (%)	91	99
	Education (%)	88	61
	Healthcare (%)	72	75
Poverty reduction	Fuelwood producers investing WR (%)	72	60
	Charcoal producers investing WR (%)	91	75
	Investment posts		
	Agriculture (%)	91	87
	Commodity trade (%)	7	7
	Livestock (%)	1	2
	Fishing (%)	1	0

[a] WR = Woodfuel revenues.

For longer-term objectives, instead of saving cash, most producers preferred to invest directly in agriculture by paying for seeds, land, or labor.

This preference for tangible assets over cash is also reflected in production. Over half of charcoal producers (56%) delay selling their charcoal; they leave it in the kilns (56%) or stored in bags (45%) to be sold when prices improve or when they need cash. Producers wait an average of 26.7 days ($\sigma = 11.5$) before selling.

4. DISCUSSION AND CONCLUSION

The study shows that producers' livelihoods are characterized by diversification, with woodfuel revenues making an important nonagricultural contribution to household income. This supports the first hypothesis that woodfuel commercialization contributes to household diversification. Around Kinshasa, woodfuel production provides the most substantial, single contribution to household income for producers (on average 47% for fuelwood and 75% for charcoal). Around Kisangani, although smaller, charcoal still forms a considerable proportion (38%) of household income. For fuelwood this contribution to producers household income is more limited (12%). The integration of commercial woodfuel production in livelihood strategies is a response to urban demand and the complementarity with agriculture.

Net returns from charcoal are higher than from fuelwood, being twice the average daily income, and rates of return to labor for fuelwood are almost the same as average income. Average net benefits are higher for Kinshasa, despite higher average production quantities in Kisangani, because of higher prices for scarce woodfuel resources.

In terms of poverty mitigation, woodfuel revenues help meet basic needs, as producers spend part of their income on food, education, and healthcare. More important for poverty reduction however, is that woodfuel provides capital for investments in other activities (mainly agriculture; some trade, livestock, and fishing). Even among the poorest households, most manage to reinvest some revenues. This contradicts the second hypothesis that predicted only a limited contribution to poverty reduction from channeling incomes to investments. A novel finding is how woodfuel, especially charcoal, can also act as a household savings account. Most savings are spent for coping with shocks, rather than in accumulating assets. Yet, charcoal is stored strategically by over half of producers for future spending as well as price optimization. This shows how producers develop noncash mechanisms that facilitate the accumulation of household resources (Beverly & Sherraden, 1999).

The reinvestment of woodfuel income in other household activities and saving also has a poverty reduction impact. Forests and trees provide "sources of rent extracted and invested in sectors with greater production potentials, allowing for a diversification of income sources" (Wunder, 2001: 1829). Khundi *et al.* (2011) suggest that charcoal revenues assist in filling income gaps for households with less agricultural production in Uganda. In contrast, this study in the DRC shows that woodfuel revenues contribute income both for daily needs and for investments in agriculture, which may contribute to higher agricultural capacity and productivity.

Production quantities vary greatly between poorer and richer producers, supporting the third hypothesis that poor producers tend to benefit least, but only for charcoal. This is, however, the more profitable and valuable product, and requires the highest level of labor and economic inputs, which the poorest are often unable to access. The poorest households produce less than half of the quantity generated by richer households, with the highest levels of production by the mid-level income category. This is in line with findings about charcoal revenues in Uganda (Khundi *et al.*, 2011), and other studies about forest products, which indicate that (moderately) wealthier households tend to benefit more (Belcher, 2005; Paumgarten & Shackleton, 2009). In contrast, fuelwood does not show a significant difference in production quantities among different income groups in Kinshasa, probably because it is just as easy to access for all households. In Kisangani, where the price of fuelwood is much lower, the poorest (<50 USD per month) sell most fuelwood. Further research is needed to obtain a better understanding of underlying reasons explaining the variation in benefits for different producers.

Woodfuel revenues help accumulating capital and reducing poverty, but caution is warranted for three reasons:

(1) Overall income of producers is still low, with 55% of producer households living on an income of less than 50 USD a month, which reflects the generally high incidence of poverty in the DRC;

(2) The poorest households benefit less from the woodfuel trade, especially for more profitable charcoal;

(3) Environmental costs are not internalized, and unsustainable harvesting is especially obvious around Kinshasa, posing a risk of losing this livelihood activity in the long-term.

This study has highlighted that woodfuel production can provide important and flexible benefits to producer households supplying urban markets. The commercial value of woodfuel thus creates opportunities for producers' livelihoods, but currently clearly trading off forest conservation. The potential of woodfuel for poverty reduction around DRC's urban centers should be integrated into forestry and energy supply plans, enabling development while maintaining the natural resource base.

NOTES

1. *Woodfuel:* all types of biofuels originating directly or indirectly from woody biomass. In this paper this includes fuelwood and charcoal. *Fuelwood:* woodfuel where the original composition of the wood is preserved. This category includes wood in the raw and residues from wood-processing industries. *Charcoal:* solid residue derived from carbonization, distillation, pyrolysis and torrefaction of fuelwood (Food, 2004).

2. See Arnold *et al.* (2006) for a comprehensive overview of the thesis and anti-thesis of the woodfuel crisis.

3. See Ingram and Schure (2010) for a complete overview of the survey forms.

4. An independent samples t-test was conducted to compare production quantities of the two production zones. For charcoal the difference in means is very small: $t(761) = -2.58$, $p = .01$, effect size (eta squared) $= 0.0067$. For fuelwood the difference is much larger: $t(232) = -10.26$, $p = .000$, effect size (eta squared) $= 0.31$.

5. $F(2, 69) = 6.7$, $p = .002$, effect size (eta squared) $= 0.16$ (large).

6. A one-way between-group ANOVA was conducted to explore the impact of income level on production quantity of woodfuel. For charcoal: Kinshasa: $F(3, 345) = 14.0$, $p = 0.000$, effect size (eta squared) $= 0.11$ (medium to large), Kisangani: $F(3, 323) = 12.3$, $p = 0.000$, effect size (eta squared) $= 0.10$ (medium to large).

7. Chi square test: χ^2 (3, $n = 314$) $= 66.2$, $p = .000$, Cramer's V $= .459$ (large effect size).

8. Chi square test: $\chi^2(2, n = 69) = 8.7$, $p = .013$, Cramer's V $= .013$ (small effect size).

9. Chi Square test: $\chi^2(2, n = 777) = 2.26$, $p = .323$

10. Annual net profit (NP) $= (n * P) - (\Sigma^c)$: for Charcoal Kinshasa $= (163.5 * 7290) - (368390 + 28490 + 304393 + 107103 + 48578) =$ 334,961 FC (405 USD); for Charcoal Kisangani $= (166.1 * 4181)$-$(76832 + 21168 + 226316 + 61302 + 63944) =$ 244,902 FC (296 USD); for Fuelwood Kinshasa $= (228 * 2236) - (107952 + 17160 + 84696 + 17133 + 44893) =$ 237,974 FC (288 USD); for Fuelwood Kisangani $= (772 * 303) - (11099 + 4968 + 61478 + 23205 + 56245) =$ 76,921 FC (93 USD).

11. Chi Square test: χ^2 (3, $n = 811$) $= 24.99$, $p = .000$, Cramer's V $= .176$. After controlling for product type, differences remain, but they are no longer significant for charcoal producers ($p = 0.064$).

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